

# Opportunities for Small-Scale Forestry in Carbon Markets

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**Abstract** This paper presents an explanatory framework of how greenhouse gas emissions offsets produced from natural and planted forests ('carbon forestry') feature in voluntary and regulated carbon markets. An introduction to the convoluted policy malaise surrounding the use of forests in regulated carbon markets is also presented. Whilst there are many opportunities and potential benefits of using forests to produce offsets, relatively few carbon forestry projects currently exist, particularly in regulated carbon markets. This seems due to financial, institutional and administrative obstacles, with prohibitive transaction costs often cited as the most prominent constraint to expanded carbon forestry development. The papers in this special issue present a wide coverage of carbon forestry development policy issues. The special issue provides a unique insight into the state of carbon forestry globally and highlights the pressing need for policy and market reform to facilitate more sustainable carbon forestry development.

**Keywords** Emissions offsets · Carbon trading · REDD · CDM · Leakage · Additionality

## Introduction

Carbon markets are critical elements in the climate change mitigation and adaptation strategies of many nations. Forests feature prominently in many forms of carbon markets. This special issue of *Small-scale Forestry* collates a series of research papers on topical issues related to the role small-scale forestry plays in carbon markets. In this introductory article, an explanatory framework of the role of

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forests in carbon markets is presented, and the relevance of each paper to important trends in international carbon market policy is discussed.

Carbon markets have been defined as those markets associated with the trade of greenhouse gas emissions offsets and regulator-issued permits (mandatory and voluntary) to emit greenhouse gases. Greenhouse gas emissions offsets are defined as tradable quanta (in tCO<sub>2</sub>e) of sequestered greenhouse gases and avoided greenhouse gas emissions that can be used by organizations to reduce their net reportable greenhouse gas emissions. Carbon markets can be categorised as regulated carbon markets or voluntary carbon markets (Dargusch et al. (2010a).

## Regulated Carbon Markets

Regulated carbon markets are defined here as those that are based on some form of government regulatory framework related to climate change mitigation. Such regulatory frameworks include those established under the United Nations Framework Convention on Climate Change (UNFCCC), encompassing the Clean Development Mechanism and the Joint Implementation schemes, and national mandatory emissions trading schemes (cap-and-trade schemes), such as the European Union Emissions Trading Scheme, the New Zealand Emission Trading Scheme, and the proposed schemes in Australia (Carbon Pollution Reduction Scheme) and the USA (heralded in the US *Clean Energy and Security Act 2009*).

National-level cap-and-trade emissions trading schemes place the onus of emissions reduction on firms (typically of larger sizes) and specified industries. Firms that hold emissions liabilities can manage the cost of their compliance obligations in various ways, including by buying permits via government-operated auctions, buying permits through the secondary market (including using various financial instruments such as derivatives), decreasing greenhouse gas emissions by implementing cleaner forms of production, restructuring their businesses so that less of their business falls under the coverage of the cap-and-trade scheme, or acquiring offsets. Of these options, offsets often provide a lower cost and reduced risk alternative. As a consequence, commercial interest in offsets has grown substantially, with the global regulated carbon market for offsets in 2008 estimated to be valued at close to US\$10 billion (Capoor and Ambrosi 2009).

Offset projects in regulated carbon markets involve the reduction, avoidance, sequestration or destruction of greenhouse gas emissions through activities that take place outside of the operational boundaries of a firm that has a liability under a cap-and-trade scheme. The main way that forests feature in carbon markets is in the role they can play in carbon offset projects (referred to here as *carbon forestry*). Forests can be grown or managed to sequester, reduce or avoid greenhouse gas emissions. Forests can also be grown on a sustainable yield basis for the purposes of producing a source of renewable energy, and used instead of a non-renewable energy source, thereby avoiding emissions which would otherwise have been produced.

In regulated carbon markets the national location of an offset project determines which scheme that project may be eligible to be registered under. The UNFCCC and its related protocols and accords (most notably the Kyoto Protocol) remain the

central conventions around which all regulated carbon markets and related cap-and-trade schemes are orientated. Under the UNFCCC, countries are distinguished on the basis of their economic development characteristics, or more specifically on what the state of those development characteristics were in the 1990s when the Kyoto Protocol to the UNFCCC were designed. Countries with more developed economies (listed in the UNFCCC as Annex I countries) including the USA, Australia, member countries of the European Union, New Zealand, Canada and Japan, are differentiated in carbon market policy and assigned different climate change mitigation obligations, compared to other countries including Russia (listed as Annex II under the UNFCCC and described as ‘economies in transition’) and countries with developing economies including China, India, Brazil, the Philippines, Indonesia and all African nations (referred to as non-Annex countries because they are not listed in an Annex to the UNFCCC). The underlying principle of this delineation is that whilst all countries share a common responsibility for climate change mitigation, those with more developed economies should bear the greatest responsibility for the global cost of emissions reductions, and that sustainable economic development in developing countries should be augmented, not constrained, by climate change mitigation policy (also known as ‘common but differentiated responsibilities’).

A consequence of this delineation is that offset projects in Annex I countries are treated differently to offset projects in Annex II and non-Annex countries. Offset projects in Annex I countries can either be developed under the Joint Implementation (JI) provisions of the Kyoto Protocol to the UNFCCC, or under the rules of cap-and-trade schemes of those Annex I countries, which should also be consistent with the provisions of the UNFCCC. For example, both the proposed Carbon Pollution Reduction Scheme in Australia and the New Zealand Emissions Trading Scheme allow for the use of offsets produced through domestic afforestation and reforestation projects. Offset projects in Annex II countries can also be registered as JI projects, but because Annex II countries do not have emissions reduction targets under the Kyoto Protocol, no Annex II countries have introduced any domestic cap-and-trade schemes. The offsets produced from registered JI projects (called Emissions Reduction Units or ERUs) can be traded and used as offsets by Annex I countries to reduce their national-level emissions, or by firms in Annex I countries to reduce their net reportable emissions, provided the domestic cap-and-trade schemes in those Annex I countries allows for the use of offsets from registered JI projects. Offset projects in non-Annex countries can be registered under the Clean Development Mechanism (CDM) of the Kyoto Protocol. Offsets produced by CDM projects (called Certified Emission Reduction units or CERs), like ERUs, can also be traded and used as offsets by Annex I countries to reduce their national-level emissions, or by firms in Annex I countries to reduce their net reportable emissions, provided the domestic cap-and-trade schemes in those Annex I countries allows for the use of offsets from registered CDM projects. The CDM is a particularly important offset scheme in international carbon markets, constituting over 85% of the total value of the global regulated carbon market for offsets (Capoor and Ambrosi 2009).

## Voluntary Carbon Markets

Offset projects in voluntary carbon markets, although aligned with the same UNFCCC-related principles of regulated carbon markets, are governed by rules that are characteristically broad and flexible. The rules governing voluntary carbon markets are typically set by the organisations participating in the market and other stakeholders who have an interest in maintaining the integrity of the voluntary schemes. The key difference between regulated and voluntary carbon markets is that organisations choose to engage in voluntary carbon markets and choose to buy offsets as a means of demonstrating their corporate responsibility and climate change mitigation efforts. In voluntary carbon markets organisations are not forced to reduce their net reportable greenhouse gas emissions but rather elect to do so for reasons other than compliance with a government-run emissions reduction scheme.

Participation in voluntary carbon markets to date has been on a much smaller scale than participation in regulated carbon markets: the value of the trade in offsets of all kinds in the global voluntary carbon market in 2008 was estimated to be almost US\$500 million, less than 5% of the total global market for carbon offsets (Capoor and Ambrosi 2009). Various standards have been developed to reinforce the integrity of voluntary carbon market schemes. The most notable and widely used of these is the Voluntary Carbon Standard (VCS) (Bayon et al. 2009). Some organisations, such as the International Airline Transport Association, have elected as a policy to only acquire offsets registered under the VCS. Provisions for offsets from both planted forests and natural forests are included under the VCS. This explains why airlines commonly offer passengers the option to offset the emissions attributable to their travel by, as many airlines describe in their marketing material, 'planting a tree'. Other voluntary carbon market trading forums, including the Chicago Climate Exchange (CCX), involve members of the exchange defining their own emissions reduction targets and agreeing to a range of rules set by the exchange for how emissions reductions can be achieved. In the case of the CCX, which is by far the largest single trading forum for voluntary carbon markets, members reduce their emissions directly, or by trading permits with other members, or by acquiring offsets approved by the exchange (Bayon et al. 2009). The CCX includes provisions for offset projects from planted forests and natural forests.

Whilst the CCX is the largest single voluntary carbon market forum, most trades of forest-based offsets in the voluntary carbon market occur directly between the offset project developer and the offset buyer (so called *over the counter* trades). In voluntary carbon markets, buyers often prefer some offset projects over others, particularly if those offset projects offer opportunities for the buyers to reinforce their corporate sustainability credentials and demonstrate to their stakeholders through their corporate reporting initiatives their efforts to be socially and environmentally responsible. This is one reason why not-for-profit organisations are prominent actors in voluntary carbon markets. A recent study of the Australian forest industries revealed that 24 new entrepreneurial firms that were primarily engaged in the business of afforestation-based offsets dominated forest-offset development in Australia and that none of Australia's traditional forest plantation firms (that had previously grown plantations for timber production) were engaged in

any major way in the development of carbon offsets. Of the 24 new firms identified, three of the four largest firms were not-for-profit companies (Dargusch et al. 2010a). This highlights an important opportunity for small-scale forestry in carbon markets; if small-scale forest offset projects can make a greater contribution to positive social and environmental outcomes than their industrial-scale equivalents, then perhaps there are greater public benefits if carbon market rules and policy, both regulated and voluntary, are structured to facilitate the development of more small-scale forest offset projects.

## Forests and Carbon Markets

Forests have received a great deal of attention in the climate change mitigation policy discourse, particularly in regards to the definition of planted and natural forests, methods to estimate carbon emissions and sinks, the socio-economics and sustainability of offset project development, and the design of carbon market policy to foster investment in forest carbon projects. Table 1 presents an explanatory framework that describes how planted and natural forests feature in both regulated and voluntary carbon markets in developed and developing country settings. The explanatory framework is intended to provide a helpful introductory tool for the reader to decipher the rather convoluted mix of regulations, rules and policies that dictate how forests feature in carbon markets.

The remainder of this paper reviews some of the key issues that influence the development of small-scale carbon offset projects. In this discussion, the use of forest biomass for renewable energy generation is not considered part of carbon markets per se although the use of forest biomass for the production of offsets (i.e. the use of a renewable feedstock in place of non-renewable feedstock to avoid emissions and produce offsets) is included. This is an important distinction because the socio-economics and policy of forest bioenergy is an important research topic in its own right.

## Defining a Forest in Regulated Carbon Market

The definition of what constitutes a *forest* in carbon markets remains contentious. In regulated carbon markets, the definition of a forest is taken from that adopted by parties of the Kyoto Protocol to the UNFCCC, namely that a forest;

is a minimum area of land of 0.05–1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10–30 per cent with trees with the potential to reach a minimum height of 2–5 meters at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10–30 per cent or tree height of 2–5 meters are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked

**Table 1** Explanatory framework the role of forests in carbon markets

| Market type   | Planted forests  |   | Natural forests   |  |
|---|--|---|---|--|
|   | Regulated  | Voluntary   | Regulated   | Voluntary  |
| Developing countries (listed under Annex I or Annex II of the Kyoto Protocol) | Production of offsets through the CDM (only afforestation and reforestation projects as defined under the Kyoto Protocol are allowed). See the papers by Tal and Gordon, and Lasco et al., in this issue   | A variety of tree planting projects not necessarily consistent with the definition of afforestation and reforestation projects under the Kyoto Protocol. One of the more common applications involves tree planting projects to offset emissions from international air travel. Further research is needed to identify the factors that influence the development of more forest carbon projects in voluntary markets | No scheme currently exists; however, much attention has been given to the opportunity to develop Reduced Emissions from Deforestation and forest Degradation + (REDD+) schemes, where emissions avoided as a result of forest conservation and rehabilitation measures can be used to produce tradeable offsets. REDD has been most commonly considered in the context of tropical forests. See the papers by Martello et al. and Dargusch et al. in this issue | Some voluntary projects have been developed involving production of offsets from the emissions avoided as a result of forest conservation. There is currently a REDD methodology under review by the Voluntary Carbon Standard and a number of forest conservation projects have been used to produce offsets traded over the Chicago Climate Exchange |
| Developed countries (so called non-Annex countries)                           | Production of offsets through the JI and some cap-and-trade schemes including the NZ ETS and proposed Australian CPRS (only afforestation and reforestation projects as defined under the Kyoto Protocol allowed). See the papers by Donaghy et al. and Charnley et al. in this issue for more information | A variety of tree planting projects not necessarily consistent with the definition of afforestation and reforestation projects under the Kyoto Protocol. One of the more common applications involves tree planting projects to offset emissions from corporate vehicle fleets  | No scheme currently exists, although the inclusion of natural forests has been discussed as an important element of the cap and trade scheme heralded in the USA's <i>Clean Energy and Security Act 2009</i> . See the paper by Charnley et al. in special issue n  | No scheme or initiatives exist   |

as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest.

So-called ‘land use, land use change and forestry’ activities are covered by two Articles (3.3 and 3.4) of the Kyoto Protocol. Activities that are included under Article 3.3 as sources of emissions or sequestration sinks in national-level greenhouse gas accounting include direct human-induced afforestation, reforestation and deforestation activities that commenced on or after 1 January 1990. Eligible activities under Article 3.4 include revegetation, forest management, cropland management and grazing land management. Nations need to take the greenhouse gas emissions impacts of these activities into account when reporting their national level emissions under the Kyoto Protocol. Importantly however, the Kyoto protocol only allows for the use of afforestation and reforestation projects (started on or after 1 January 1990) for use as offsets in regulated carbon markets. Avoiding deforestation and reduction of forest degradation efforts cannot currently be developed into carbon offsets for use in regulated carbon markets. This critical limitation has led to efforts to develop Reduced Emissions from Deforestation and Degradation (REDD) carbon market policy (), which would enable forest conservation initiatives to be used as offsets. The concept of REDD is discussed the following papers by Dargusch et al. and Martello et al. in the context of tropical forests in developing countries and by Charnley et al. in the context of natural forests in the USA.

The UNFCCC definition of a forest and the Kyoto protocol provision to recognize only forests planted after 1990 (on sites cleared before 1990) as offsets constrains inclusion of forests in carbon markets. The spatial parameters of the definition do not take into account regional variation in forest types (e.g. what people generally consider to be a forest in tropical Indonesia differs greatly in structure and density of tree cover to what people consider to be a forest in temperate woodland systems in semi-arid Australia). This could lead to existing forests being exploited to the extent that the resulting forest structures could still fall within the definition, with emissions from the deforestation and forest degradation going unreported. The 1990 Kyoto delineation creates further difficulties, particularly for developers of afforestation and reforestation offset projects in developing countries where it is difficult to present verifiable proof that project areas were cleared before 1990. Furthermore, the UNFCCC definition of a forest makes no distinction between natural forests and industrial plantations planted established before 1990. Revisions of the UNFCCC definition of a forest are required to enable greater inclusion of forests in regulated carbon markets.

## Planting Trees for Carbon Offsets

The opportunity to produce carbon offsets from planted forests presents numerous opportunities to promote the multiple environmental and socio-economic benefits potentially offered by tree growing. But in practice, relatively few tree planting offset projects have taken place since the introduction of regulated carbon markets.

For example, in an analysis of all 6109 CDM projects in the CDM ‘pipeline’ (of proposed and registered projects) as at 1st July 2010, Thomas et al. (2010a) found that less than 1% of all projects were afforestation or reforestation projects. This dearth of carbon forestry projects under the CDM can be attributed to financial, administrative and governance factors (Thomas et al. 2010b). These factors are highlighted in the following papers. For example, in a discussion of the history of afforestation development in Israel (considered a non-Annex country under the UNFCCC), Tal and Gordon explain that several factors discourage forestry carbon projects, including administrative obstacles associated with international accreditation, potential economic profitability of tree planting and ethical considerations. Tal and Gordon further explain that in Israel, because of the biophysical features of the semi-arid landscape and socio-political issues affecting land availability, in afforestation projects trees are typically slow-growing and mostly restricted to small-scale developments. The authors argue that under those conditions, if the price for offsets were between \$US 3-7/tCO<sub>2</sub>e, the costs of registering and monitoring a CDM project would be prohibitive for most carbon forestry developments. The authors suggest that only in cases of comparatively large forest stands of 2000ha or greater would carbon forestry be profitable in Israel.

Prohibitive transaction costs involved in afforestation and reforestation projects have often been cited as reasons why so few carbon forestry projects have been developed under the CDM. Such costs not only include the registration and monitoring costs of a CDM project, but also the up-front capital costs required to establish tree plantings. Moreover, financial returns from forestry carbon projects typically are not realized for a decade or more after project commencement. Other types of CDM projects that yield tradeable offsets soon after project commencement, such as renewable energy and energy efficiency projects, typically provide much more attractive financial propositions, and have attracted a greater share of the CDM investment market. Lasco et al. in this issue highlight the prohibitive nature of transaction costs in community-based agroforestry tree planting projects in the Philippines. Through detailed analysis of three case studies, the authors claim that income from offsets is not sufficient to cover the costs of tree planting and that transaction costs act as the greatest barrier to the development of small-scale carbon forestry projects in the Philippines. Lasco et al. observe that voluntary carbon markets might present an avenue to overcome these transaction cost constraints, given the flexibility around forest eligibility and lower registration cost requirements in those markets.

Charnley et al. in this issue review opportunities and challenges in carbon markets for small-scale forestry projects in the USA (an Annex I country of the UNFCCC, but yet to ratify the Kyoto Protocol). These authors suggest that numerous socio-economic factors constrain greater numbers of US landowners from engaging in carbon forestry, including the conflict in managing forests for carbon and for other forest management objectives. Like the analyses presented by Tal and Gordon for Israel, and Lasco et al. for the Philippines, Charnley et al. highlight the high transaction cost involved in small-scale carbon forestry projects, which seems to be the greatest constraint to increased landowner engagement in carbon forestry in the USA. Transaction costs are identified by the authors as a key issue for climate

policy-makers in the USA to resolve given that over half of the forest area in the USA is owned by private landowners and that the current Obama administration has publicly declared interest in establishing a domestic cap-and-trade scheme that includes provision for offsets to be produced from both planted and natural forests.

Donaghy et al. investigate similar issues for the case of agroforestry carbon projects developed in low rainfall regions of northern Australia. These authors evaluate the financial feasibility of six types of silvopastoral management options, including growing trees for carbon offsets and timber in combination with cattle production. Their analysis takes into account regional costs and prices for offsets, timber and cattle production, and incorporates uncertainty surrounding these variables through sensitivity analysis. Their analysis reveals that at an offset price of greater than AU\$10 per tCO<sub>2</sub>e, landowners would be financially better off over 25 years to continue to graze but retain strips of regrowth for the purposes of offset production. These authors conclude that the production of forest carbon offsets could be financially viable in northern Australia if tree growing is integrated with cattle production in agroforestry systems. Given the vast areas of land used for cattle production in northern Australia, Donaghy et al. argue that climate policy and agricultural extension services in Australia would provide a useful service by informing and empowering graziers to engage in these opportunities.

## Conserving Forests for Carbon Offsets

There are three major reasons why a scheme that enables tradeable offsets from conservation activities in natural forests (a so-called REDD+ scheme) should be developed. First, this would recognize deforestation and forest degradation, particularly in tropical forest countries, as a major source of global greenhouse gas emissions, and offer an opportunity to abate those emissions by attracting funds, via revenue from offset sales, to support conservation activities. Secondly, REDD+ offers a potentially cost-effective method for reducing global emissions—the cost of producing offsets has been estimated to be relatively low (Schlamadinger et al. 2007). Thirdly, REDD+ potentially offers many environmental, social and economic benefits (such as income and better water quality), particularly for people in developing countries. Dargusch et al. in this issue expand on these issues and review some of the main features of proposed REDD+ policy, and the reasons for the impasse on implementing such a policy under the UNFCCC.

Aside from the issue of emissions reductions, there is potential for REDD+ to provide a framework to address tropical deforestation management. Tropical primary forests and the biota they support are favoured recipients of donations for environmental projects and conservation, and feature in existing voluntary carbon markets. Yet despite years of campaigning and the presence of iconic species, deforestation rates in tropical forests have continued to persist. A persistent and recurring problem in attempts to halt deforestation has been the issue of *leakage*, where projects have merely relocated deforestation impacts rather than abating them. Leakage is one of the major factors that prevented REDD-type activities from being included in the Kyoto Protocol (Strassburg et al. 2009). Martello et al. (this

issue) present a systems analysis of the factors affecting leakage in REDD+ schemes. They argue that one of the key intervention points for stakeholders to avoid the negative effects of leakage is to provide livelihood alternatives to supplement the resources and income that neighbouring small-scale communities must forego for REDD+ initiatives to be successful. But the authors also note that challenges remain concerning how best to distribute these supplementary resources, and that the lack of institutional capacity in many countries might constrain effective and fair distribution of financial returns, which in turn could hamper the long-term chances of success of REDD+ schemes.

Other major methodological and market issues hindering the acceptance of REDD+ include accurate monitoring and reporting, methods to estimate emissions from several land and forest types, and addressing the requirement of *additionality* (demonstrating that emissions reductions occurring as a result a project would not otherwise have taken place). There has also been concern that large developed nations would use *hot air* credits (credits that some observers believe have effectively no climate change mitigation benefit) to reduce the need to make real emissions cuts internally (Strassburg et al. 2009), and moreover that by using offsets from REDD+ projects, developed countries would reduce the options available for developing countries to reduce their own national emissions at a later date (Olsen 2007). It is also difficult to design a REDD+ scheme that is universally applicable. An international REDD+ scheme design must be flexible enough to provide incentives for countries in all stages of forest conversion (Strassburg et al. 2009), and for many forest types, and many forms of forest degradation (Sasaki and Putz 2009). There is a danger that scheme designs that favour particular types of countries or forests over others could result in *international leakage* (Strassburg et al. 2009), or that focus on one benefit such as carbon sequestration could result in degradation of other benefits such as biodiversity.

Investment in REDD+ is also associated with risk, whether from miscalculation of emissions reductions or through loss due to fire or other biophysical events. If REDD+ policy is to be a national government-to-government framework, it is likely that risk of non-delivery of offsets would lie with the supplying (developing) country. This could provide a more secure international offsetting option for developed countries than the current Clean Development Mechanism market, which is project-based and where the burden of delivery risk lies predominantly with the developed country buyer. Overall, development and investment in REDD+ mechanisms and projects appear to offer considerable benefits for many developed countries, and it is therefore not surprising that many of them support REDD+. However, there is no decision by the UNFCCC up to now whether the REDD+ scheme will be implemented at a national or sub-national (local or project based) approach.

The inherent challenge for a REDD+ mechanism, and the key to its success, is providing adequate compensation to developing countries for the services they provide. Essentially, the adequacy of compensation requires that payments be at least equal to the opportunity cost of foregoing other forms of forest use. Whether compensation meets opportunity costs will depend on two factors: the value of the payments (likely linked to the price of carbon), and the value of the forgone

opportunities. If REDD+ generates carbon offsets for trade in the international market then carbon prices will vary according to supply and demand.

## Conclusion

Forests feature prominently in the carbon market discourse, and many opportunities exist for the economic, social and environmental benefits of sustainable forest management to be promoted by the development of carbon offsets from forests. But to date relatively few offset projects involving either natural or planted forests have been developed, and numerous financial, institutional and governance constraints have been proffered as explanations. A key challenge for concerned stakeholders is how to address these constraints. Thomas et al. (2010b) investigated possible solutions to these challenges by examining the key features of the four afforestation CDM projects that had been successfully registered as of 1st July 2009. Analysis revealed that in all four projects initial funding support was provided by an external organisation, design and implementation of the project was guided by a large organization with technical expertise in CDM projects, the project occurred on private land (with comprehensive property rights), and most revenue from offsets was directed back to the local community. Thomas et al. (2010b) argued that the CDM needs to be reformed to incorporate greater flexibility, simplifying the methodological and documentation procedures of CDM registration, and redefining the role of the UNFCCC in CDMs from one of adjudication to one of facilitation. It seems that only with such structural reform of carbon market policies and administrative arrangements, and perhaps further financial incentives in carbon markets towards carbon forestry, will the potential social, environmental and economic benefits of carbon forestry be realised.

Carbon forestry can also support the adaptive capacity of vulnerable communities to deal with climate change and, if managed sustainably, can complement ecological services and food production. Opportunities for carbon forestry may lie in combining forest management with land use activities (such as in agroforestry as suggested by Donaghy et al. in this issue), or even other emerging enterprises such as bioenergy production or the sequestration of soil carbon. Moreover, climate change policies currently focus on reducing the concentration of atmospheric greenhouse gases, but pay limited attention to feedbacks between the land surface and the climate system. Forests and woodlands play an important role in the climate system by buffering climate extremes, maintaining the hydrological cycle and sequestering carbon, but tropical deforestation continues apace. Reduction of the potential impact of climate variability and change on society and the environment therefore requires a broader focus of environmental sustainability and resilience that is underpinned by the restoration of feedbacks between vegetation and climate. There is a pressing need for stronger integration of land-use and climate change policies and an acceleration of investment in strategic reforestation, especially in tropical and sub-tropical regions. The research presented in this issue makes a valuable contribution to the identification of key areas for further research and the policy developments required to address this need.

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